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(Article begins on next page)

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A trip through deep time in the rock succession of the Marguareis area (Ligurian Alps, South Western Piemonte)

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Abstract

Within the multidisciplinary research project "PROGEO-Piemonte", aimed to achieve a new conceptual and operational discipline in the management of the geological heritage of the Piemonte Region, an itinerary is proposed in order to illustrate the most significant steps in the geological evolution through time of the stratigraphic successions exposed in the Marguareis area (south western Piemonte) that geologically belongs to the Ligurian Briançonnais Domain. Here, rocks of very different nature (volcanic and sedimentary), and depositional environment (continental alluvial plains, carbonate tidal flats, deep sea basins) crop out and provide the solid record of a very long time span (from Permian to Eocene: over 200 million years). On the whole, they record the main stages of the geological evolution of the European margin related to the opening and closure of the Alpine Tethys ocean and consequent genesis of the Alpine chain. The proposed itinerary, moreover, enables to show how the stratigraphic successions may be discontinuous with prolonged gaps, and how the occurrence of ancient faults may be documented by the geometrical relationships between rock bodies.

Introduction

One striking feature of mountain chains is the exposure, often spectacular, of huge rock masses that not uncommonly are of sedimentary origin and contain fossils. They bear a very important geological significance as they represent the materialization of the geological time and show features (lithology, sedimentary structures) that allow to infer ancient depositional environments. Moreover, stratigraphic successions are often separated by discontinuity surfaces mainly due to erosion. Sedimentary rocks therefore, may be considered as natural archives of all the chemical, physical and biological evolutionary changes that took place through geological time on our planet.

In the Piemonte sector of the Alps, sedimentary successions are best exposed in the western part of Ligurian Alps where altitude and rock composition concur to provide superb geological exposures. This area is particularly complex as it appears as a mosaic of different units (Pre-Piemontese, Ligurian Briançonnais, Dauphinois), pertaining to the European Mesozoic passive continental margin of the Alpine Tethys, or to the Alpine Foreland Basin i.e. the basin developed above the European margin during the first collisional stages that generated the Alpine chain. These units are at present juxtaposed and superposed by tectonic processes and, on the whole, record the main stages of the geological evolution of the European margin related to the opening and closure of the Alpine Tethys ocean and consequent genesis of the Alpine chain. These features, moreover, are spectacularly exposed in a protected area (Marguareis Park), easily visitable through well indicated trails.

This research falls within the multidisciplinary project “PROGEO-Piemonte” (PROactive management of GEOlogical heritage in the PIEMONTE region, Giardino 2012) and has the goal to project a series of itineraries developed in a GIS environment, from the Marguareis Massif to the Colle di Tenda (Cuneo), aimed to illustrate, in a scientifically correct way, but accessible to a large public, from non-specialists to academic geologists, the most significant steps in the geological evolution through time of the rock successions exposed in the area. These itineraries represent an example of the possibility of dissemination of geological knowledge starting from disciplinary scientific researches. The case chosen allows to tell the story of a sector of the Alpine chain through deep time to a wide public directly on the field. Its location within a protected area crossed by a network of well-tracked mountain trails makes it easily accessible, and will provide tourists with the opportunity to increase their scientific knowledge of the Earth.

Geological setting

The geological knowledge of the Ligurian Briançonnais successions and their evolutionary model is based on the existing scientific literature, mainly produced in the 70's and 80's (Campredon et al. 1967; Vanossi 1970; Gosso et al. 1983). In the last years new multidisciplinary studies based on 1:10.000 scale geological mapping have been carried out by the authors. These studies resulted in original data on the stratigraphic and structural setting of this domain (Piana et al. 2009; Bertok et al. 2011, 2012), which allowed new interpretations of its geological history.

The area crossed by the proposed itinerary is located in the Marguareis Alps (sensu Marazzi 2005), corresponding to the westernmost part of the Ligurian Alps. It belongs to the central part of the External Ligurian Briançonnais (Fig. 1), and is composed of kilometre-scale tectonic units which, although intensively strained at certain stratigraphic levels, show a very low grade metamorphism and retain primary sedimentologic features and original stratigraphic relationships (Piana et al. 2009).

The succession cropping out in the Ligurian Briançonnais begins with volcanic and volcanoclastic rocks of Carboniferous–Permian age (Boni et al. 1971) followed by a condensed Mesozoic succession deposited above the European continental margin of the Alpine Tethys. The succession ends with Cenozoic sediments deposited in the Alpine Foreland Basin during the early collisional stage of the Alpine chain. The Ligurian Briançonnais succession is subdivided into several lithostratigraphic units bounded by discontinuity surfaces corresponding to important hiatuses (Vanossi 1970, 1972; Vanossi et al. 1984; Boni et al. 1971; Bertok et al. 2011; Bertok et al. 2012) (Fig. 2):

- Quarziti di Ponte di Nava (QPN) (Upper Permian?–Lower Triassic). Fluvial to littoral conglomerates and cross-bedded quartzarenites, locally interbedded with shales (up to 110 m thick).
- Peliti di Case Valmarenca (PCV) (Lower Triassic). Lagoonal red to purple mudrocks, locally interbedded to siltstones. They were intensively deformed and delaminated during Alpine tectonics and thus it is impossible to estimate their real thickness.

- Dolomie di S. Pietro dei Monti (DSPM) (Anisian–Ladinian). Peritidal dolomites and limestones (200–400 m thick). The top of the DSPM is truncated by an erosional surface corresponding to a hiatus which spans the Late Triassic, Early Jurassic and part of the Middle Jurassic.
- Calcari di Rio di Nava (CRN) (Bathonian). Dark micritic limestones, locally bioclastic in the lower portion, that are intensely laminated and nearly barren of fossils in the upper portion (about 50 m thick); conglomerates composed of Triassic dolomite clasts are locally present at the base. A restricted carbonate shelf environment may be inferred (Bertok et al., 2011). The top is truncated by an erosional surface, locally associated with an angular unconformity.
- Calcari di Val Tanarello (CVT) (Kimmeridgian?–Berriasian). Pelagic succession consisting of crinoidal limestones at the base and massive light micritic limestones, locally exhibiting a nodular Ammonitico Rosso facies, in the upper part. The thickness of the CVT is variable (25–70 m).
- Formazione di Upega (FU) (Upper Cretaceous). Grey marly limestones interpreted as slope hemipelagic sediments. These marly limestones are separated from the underlying CVT by a black crust of Fe–Mn oxides, glauconite and phosphates containing planktonic foraminiferal assemblages referable to the middle Albian–Cenomanian (Bertok et al. 2011). This mineralized hard ground documents a prolonged hiatus encompassing the Valanginian–Aptian interval and may be referred to palaeoceanographic changes. The FU is crossed by an Alpine pervasive foliation that documents a strong localization of the deformation during Alpine orogenesis, due to the rheological contrast with respect to the underlying, massive carbonate formations (Piana et al. 2009). For this reason the real stratigraphic thickness of the formation may be only approximately estimated to several tens of metres.
- Calcari della Madonna dei Cancelli (CMC) (Bartonian-Priabonian). Foramol-type ramp massive bioclastic limestones, with abundant macroforaminifera (*Nummulites*, *Discocyclina*) referable to early Bartonian, transitionally followed by pervasively foliated dark marls with interbedded calcareous beds referred to the Priabonian by Lanteaume et al. (1990). An important discontinuity surface is present at the base with a hiatus

encompassing the uppermost Late Cretaceous, the Paleocene and part of the Eocene. The maximum thickness of the CMC is 30 m.
- Flysch Noir (FN). Dark argillaceous sediments, locally interbedded with turbidite sandstone layers, that have been tentatively assigned to the late Priabonian (Guillaume 1969; Michard and Martinotti 2002).

Description of the itinerary and of the Stops along the trail

In this paper, a first itinerary is proposed which is developed along a very well marked and renown trekking trail (GTA: Grande Traversata delle Alpi) that starts from Valle Ellero (Rifugio Mondovì) and leads to the Colle dei Signori (Rifugio Don Barbera), in part within the area of the Marguareis Park, in part in the adjacent area SIC (Site of Community Importance) (Fig. 3). Along this way the entire geological history (Late Palaeozoic to Eocene for a total time span of over 200 million years) of this part of the Ligurian Briançonnais may be followed.
Starting from Rifugio Mondovì, and climbing up to the Biecai Pass, it is possible to see in the landscape cliffs of Lower Triassic conglomerates and sandstones, (better exposed in Stop 3), representing the first sediments deposited over the Permian volcanic rocks in continental to marginal marine environments under the effect of currents as documented by different kinds of sedimentary structures (parallel lamination and cross bedding).
Above these deposits, Middle Triassic carbonate rocks outcrop. They are mainly dolostones and record the transition to a completely different environment consisting of a widely extended, very shallow carbonate platform affected by tides. The most typical facies are better observable in stop 4.

Stop 1

Just below the Biecai Pass, the top of the Middle Triassic dolostones is represented by a thin and discontinuous layer of breccias with dolomite clasts and yellow to reddish matrix. Such breccias are classically interpreted as the result of dissolution and karstification of the Triassic carbonate rocks during a period of subaerial exposure and document vertical displacements and tilting of blocks along rift-related normal faults.

Immediately above, the presence of dark grey limestones of Middle Jurassic (Bathonian) age demonstrates that the emersion phase was very long as it encompassed the Late Triassic and the Early Jurassic (about 60 million years). In other close localities fossil bivalves and gastropods occur at the base of these Middle Jurassic limestones showing that a normal marine, shallow water environment was settled by that time as a result of downward vertical movements related to a generalized renewed post rift subsidence. The depositional environment of the Middle Jurassic limestones is interpreted as a sort of lagoon partially isolated from the open sea, occasionally affected by high-energy events, probably related to storms, leading to the deposition of dm-thick beds of matrix- to clast-supported lithoclastic breccia (Fig. 4).

At the Biecai Pass a sharp surface, possibly associated to another gap but of much shorter duration, separates the Middle Jurassic grey limestones from Upper Jurassic reddish to whitish limestones that in other areas of the Marguareis Massif contain ammonites and document a typical pelagic environment. A sea water depth increase, in other words, is clearly recorded by this lithological change.

Stop 2

Proceeding towards the Colle del Pas, the attention is kept by the reddish brown rocks of which the mountain ridge extending from the Colle del Pas to Colle Sestrera is made. They are Permian rhyolites that perfectly preserve the magmatic structure made of whitish k-feldspar phenocrystals in a reddish microcrystalline groundmass (Fig. 5)

Stop 3

Stepping down the Colle del Pas and watching northward, a very extensive outcrop of reddish Permian volcanic and volcanoclastic rocks, including rhyolites, are clearly visible. They are abruptly bounded to the east by an east-dipping steep surface over which the Upper Cretaceous marly limestones (Formazione di Upega) lie with a primary stratigraphic contact marked also by a thin body of fine-grained breccias mainly made of clasts of Permian volcanics. This anomalous contact is interpreted (Bertok et al. 2012) as a submarine escarpment related to a Late Cretaceous normal fault that displaced down

the eastern block by some hundreds metres and was covered by talus breccias and then by hemipelagic marine sediments (Fig. 6).
Along the trail beautiful outcrops of Permian and of Lower Triassic rocks may be observed. Permian rocks are easily recognized for their pink to reddish colour (Fig. 7). They consist of volcanosedimentary rocks including both epiclastic and pyroclastic products, i.e. respectively the results of erosion and transport as clasts of volcanic rocks and of falls and flows of pyroclastic material, ranging in size from fine ash to boulders. Sedimentary structures, such as bedding, grading and internal lamination, document the volcanosedimentary origin of these rocks and therefore an intense volcanic activity with a strong explosive character.
A few tens of meters further to the south along the same trail, other large outcrops are present in which whitish rocks are exposed. They consist of interbedded sandstones, pebbly sandstones and conglomerates in thick to very thick beds bounded by erosional surfaces and internally showing good examples of large scale trough cross bedding (Fig. 8). Lithology and sedimentary structures point to an alluvial depositional environment characterized by braided streams with a sand-gravel bedload. The whitish colour is due to the great abundance of quartz both as sand grains and pebbles and cobbles. This composition is probably due to the recycling of coarse-grained clastic sediments of Permian age characterized by a high degree of compositional maturity and making part of the stratigraphic succession of the Dauphinois Domain, currently cropping out to the south-west of the Marguareis area.

Stop 3a

Leaving aside the main trail and going to the left hand side of the valley, close to the Saracco Volante hut, grey massive limestones (Fig. 9) are recognizable just above the top of the Upper Cretaceous hemipelagic marly limestones (Formazione di Upega). They contain Middle Eocene macroforaminifera (nummulitids) that indicate two important geological facts: 1) the water depth was again shallow enough to allow life of these benthic organisms, typical of mid-latitudes inner shelf environments; 2) another important gap (more than 20 million years) is recorded that in other areas of the Maritime and Ligurian Alps is associated to evidence of emersion and subaerial exposure.

Stop 4

The trail then continues within Dolomie di San Pietro dei Monti, that consist of dm-thick beds of finely laminated dolostones with desiccation-related shrinkage pores and vugs, and massive fine-grained dolostones showing millimeter-large dolomite pseudomorphs of gypsum crystals (Fig. 10). Such features document a very shallow carbonate platform environment periodically affected by tides, in arid, sabkha-like conditions.

Stop 5

The last tract of the itinerary, towards the Colle dei Signori, develops along the boundary between the Upper Jurassic Calcari di Val Tanarello, consisting of massively bedded white pelagic limestones, and the Upper Cretaceous Upega Formation made up of grey hemipelagic marly limestones. The bounding surface is clearly identifiable because of the presence of patches of a blackish crust. This mineralized hard ground (Fig. 11) documents a complete interruption of sedimentation, likely due to submarine current activity wiping away sediment from the top of submerged plateaus allowing precipitation of authigenic minerals such as phosphates, glauconite, Fe-Mn oxides. This crust contains planktonic foraminifera indicating the late part of the Early Cretaceous. More than 30 million years, therefore, are again missing in the stratigraphic record. The overlying Upper Cretaceous marly limestones were deposited in a quite deep marine environment characterized by a clay input from emerged lands. These softer rocks were also much more affected by Alpine deformation than the underlying more massive limestones and dolostones and thus appear intensely folded, foliated, and crossed by several cleavage systems (Fig. 12).

Conclusions

The proposed itinerary from Valle Ellero to Colle dei Signori will may be used for different purposes targeting a diversified public, from non-specialists to academic geologists. It is particularly suitable as a geoturistic trail and for didactic field trips at an undergraduate level for two reasons: the occurrence within a protected area, and the remarkable scientific value of this sector of the Ligurian Alps. The itinerary develops in a high mountain environment and is comprised partly within the area of the Marguareis

Park, and partly within the adjacent area SIC (Site of Community Importance*).* This implies on one hand that wide outcrops of substrate rocks favour observation of the geological features, and on the other hand that the whole area is protected and crossed by a network of well maintained mountain trails.

The itinerary is going to be developed as a virtual tour that will be hosted on the "PROGEO-Piemonte" project web-site (www.progeopiemonte.it) and made suitable for mobile technologies (Bertok et al., 2013). The track of the itinerary will be placed on a Google Maps platform and the stops will be queryable and provided with a large amount of information at all spatial and temporal scales (descriptions, field pictures, panoramic views, microscopic images of selected features, drawings, schemes, etc.). Such information will be organized at increasing levels of scientific detail. The first level will be addressed to non-specialist geoturists and school classes, and thus will be characterized by basic geological descriptions and concepts explained in a simple language, avoiding specialistic terms. Specific links to additional data will allow the users with a geological background, or at least a scientific degree, to go deeper into the proposed topics up to the state of the art of the most recent academic research. Thanks to an existing scientific agreement between the Department of Earth Sciences of the Torino University and the Marguareis Park, aimed to promote the dissemination of the geological heritage of the Park to its visitors, the present proposal will give rise in a near future to the realization of a geological itinerary. Such itinerary will be integrated in the park touristic programs and equipped with traditional explicative panels located on the trail, reporting the same information as in the first level of the virtual tour. At that time, the virtual tour will become a tool complementary to the real one, suitable both as an alternative in the case of restricted accessibility (e.g. rainy days, during winter, persons with a physical disability) or to deepen the knowledge before or after the visit in place.

As to the geological meaning, in a one-day walk an amazing trip through deep time and different sedimentary environments can be made. More than 200 million years separate the oldest rocks, i.e. the Permian volcanic and volcano-sedimentary rocks, from the youngest Eocene limestones. Such a very long time range, however, is materialized by a relatively thin rock package (less than 1000 meters) because half the total geological time is not represented by rocks but just by discontinuity surfaces separating rock bodies. The latter show completely different chemical, mineralogical and textural features that may be easily distinguished also by non-specialists and that can be interpreted as the result of sedimentation in diverse environmental and climatic conditions. Over an area covered by the Late Paleozoic products of explosive volcanic activity, Early Triassic braided rivers flowed and transported quartz-rich sands and gravels; these continental environments were replaced, in Middle Triassic, by a very shallow marginal marine platform located at tropical latitudes where sedimentation was controlled by arid climate and tides, and sediments were produced in situ and had a carbonate composition. A Late Triassic to Early Jurassic rift-related fault activity provoked the fragmentation and uplift of this very extended tidal flat with consequent interruption of sedimentation and emersion. The renewal of sedimentation took place in Middle Jurassic in a carbonate shelf environment evolving, in Late Jurassic, to a drowned pelagic plateau, and then to a slope where fine-grained terrigenous sediments mixed with pelagic carbonate oozes. Another important, tectonic-related, uplift is finally recorded by the Eocene bioclastic limestones deposited in shallow marine environments at mid-latitudes where a temperate climate prevailed. This complex evolution demonstrates how faithfully sedimentation records environmental changes that in turn are related to up and down movements of the surface eventually due to tectonics i.e. to the dynamic life of our planet Earth.

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CAPTIONS

Fig. 1 – Geographic and geological setting of the study area (red square). TPB: Tertiary Piedmont Basin.

Fig. 2 – Log of the stratigraphical succession of the study area. QPN: Quarziti di Ponte di Nava; PCV: Peliti di Case Valmarenca; DSPM: Dolomie di S. Pietro dei Monti; CRN: Calcari di Rio di Nava; CVT:

Calcari di Val Tanarello; FU: Formazione di Upega; CMC: Calcari della Madonna dei Cancelli; FN: Flysch Noir.

Fig. 3 – Simplified geological map of the area surrounding the proposed itinerary. Encircled numbers refer to the stops described in the text. Labels of the lithostratigraphic units are the same as Figure 2.

Fig. 4 – Stop 1, just below the Biecai Pass, northern slope: base of the CRN. Angular clasts of the Triassic dolostones (DSPM) occur in the lower half of a bed of the grey CRN limestones. Pencil as a scale is 14 cm long.

Fig. 5 – Stop 2, north of Colle del Pas. Block of Permian rhyolites fallen down the mountain slope and observable along the trail. Note the reddish colour of the groundmass and the whitish K-feldspar phenocrystals.

Fig. 6 - Stop 3, Colle del Pas (as seen from the south). Panoramic photograph and line drawing showing the relationships among rock bodies that document the existence of a Late Cretaceous, submarine, fault-related palaeoescarpment. PV: Permian volcanic and volcanoclastic rocks; QPN: Quarziti di Ponte di Nava; FU: Formazione di Upega; FN: Flysch Noir.

Fig. 7 - Stop 3, south of Colle del Pas, along the trail. Fine- to relatively coarse-grained volcanoclastic Permian sediments. Note normal grading and faint parallel lamination in the upper thicker bed. Head of hammer for scale.

Fig. 8 - Stop 3, south of Colle del Pas, along the trail: Quarziti di Ponte di Nava. Interbedded sandstones and conglomerates in thick to very thick beds. Note large scale cross bedding in sandstones in the foreground (the laminated interval is about 80 cm thick).

Fig. 9 - Stop 3a, south of Colle del Pas, close to Saracco Volante hut: Calcari della Madonna dei Cancelli. Detail showing an axial section of *Nummulites*. Other smaller macroforaminifera are also observable.

Fig. 10 – Stop 4, along the trail to Don Barbera hut: Dolomie di S. Pietro dei Monti. Detail showing former small gypsum crystals (now replaced by white dolomite) within a fine–grained massive grey dolostone.

Fig. 11 – Stop 5, few hundred meters east of Don Barbera hut: top of Calcari di Val Tanarello. Patches of a blackish to reddish crust made of Fe-Mn oxides and subordinate phosphates and glauconite documenting a submarine discontinuity surface. Lens cap as a scale is 4,5 cm in diameter.

Fig. 12 – Stop 5, few hundred meters east of Don Barbera hut: Formazione di Upega. The grey marly limestones appear folded and affected by two approximately perpendicular systems of pervasive foliation. Pencil as a scale is 14 cm long.

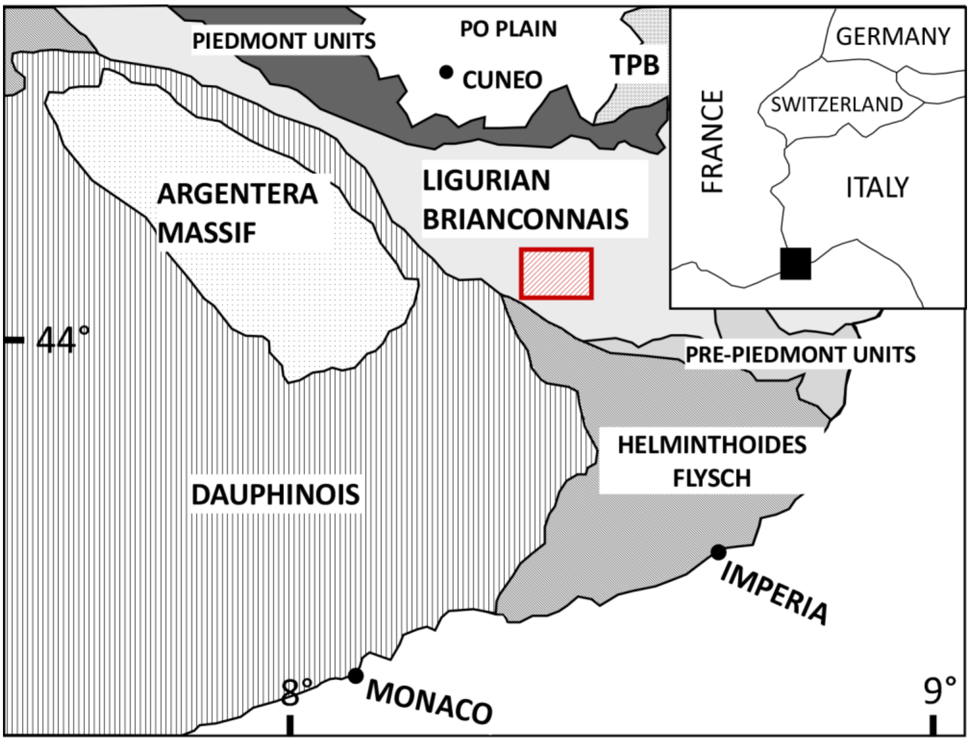
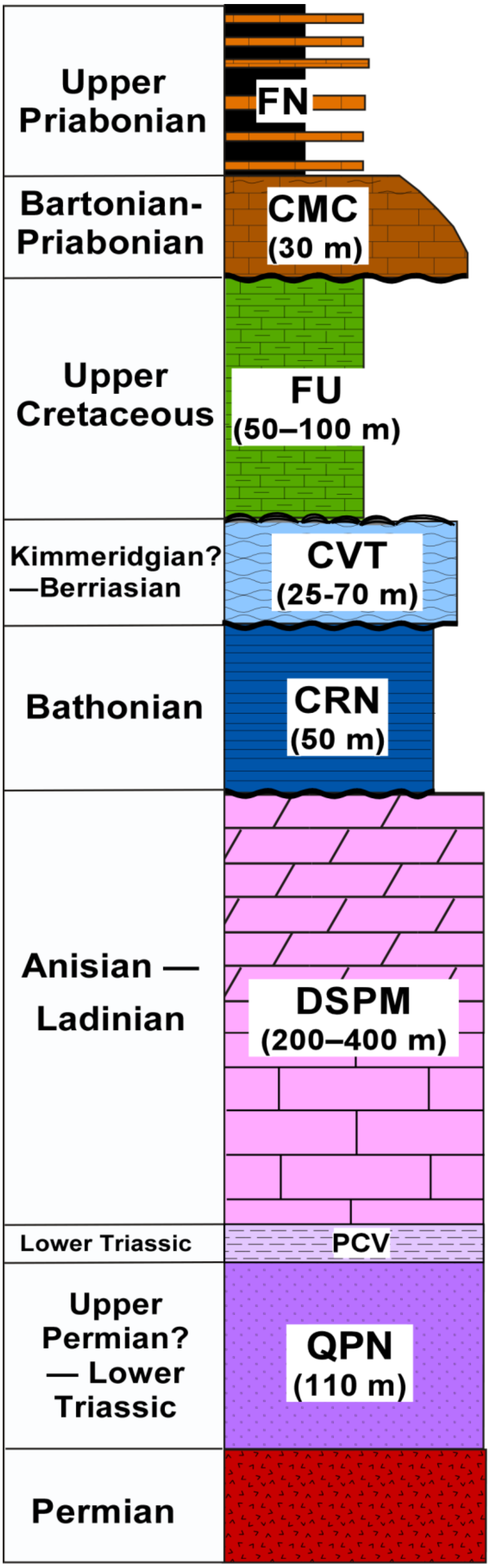
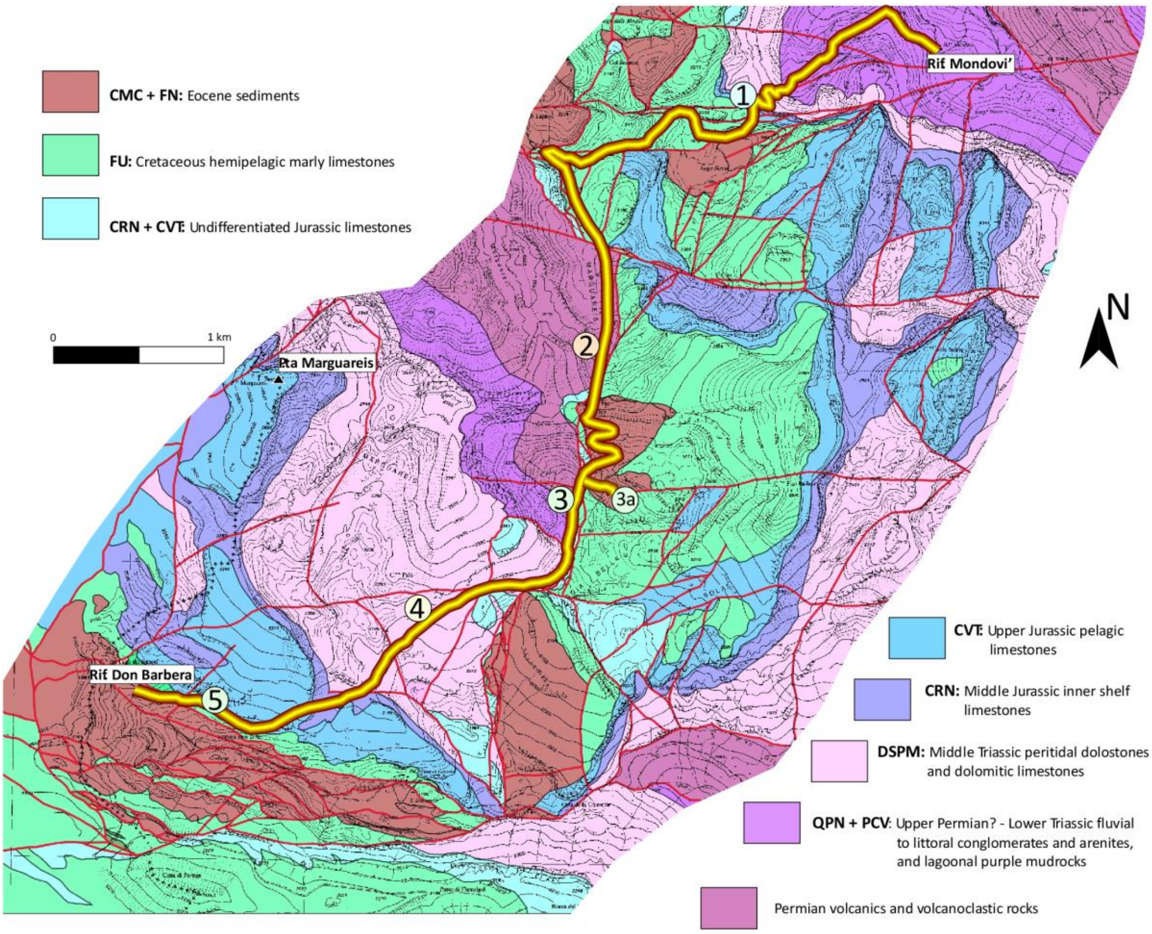

PIEDMONT UNITS
PO PLAIN
CUNEO
TPB
GERMANY
SWITZERLAND
FRANCE
ITALY
ARGENTERA
MASSIF
LIGURIAN
BRIANCONNAIS
44°
PRE-PIEDMONT UNITS
HELMINTHOIDES
FLYSCH
DAUPHINOIS
IMPERIA
8°
MONACO
9°

Fig. 1


Upper Priabonian
FN
Bartonian-Priabonian
CMC
(30 m)
Upper Cretaceous
FU
(50–100 m)
Kimmeridgian?
—Berriasian
CVT
(25-70 m)
Bathonian
CRN
(50 m)
Anisian —
Ladinian
DSPM
(200–400 m)
Lower Triassic
PCV
Upper Permian?
— Lower Triassic
QPN
(110 m)
Permian
Fig. 2



CMC + FN: Eocene sediments
FU: Cretaceous hemipelagic marly limestones
CRN + CVT: Undifferentiated Jurassic limestones
0
1 km
Pta Marguareis
Rif. Mondovi’
Rif. Don Barbera
1
2
3
3a
4
5
N
CVT: Upper Jurassic pelagic limestones
CRN: Middle Jurassic inner shelf limestones
DSPM: Middle Triassic peritidal dolostones and dolomitic limestones
QPN + PCV: Upper Permian? - Lower Triassic fluvial to littoral conglomerates and arenites, and lagoonal purple mudrocks
Permian volcanics and volcanoclastic rocks

Fig. 3

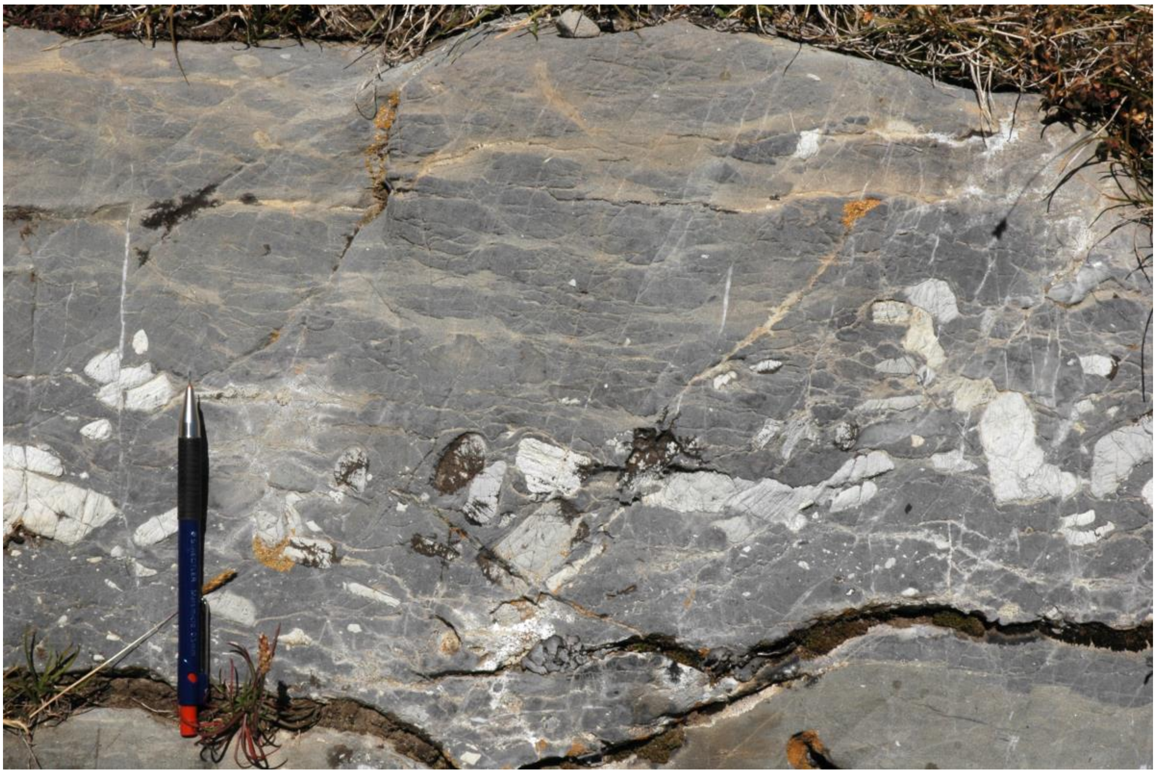


Fig. 4

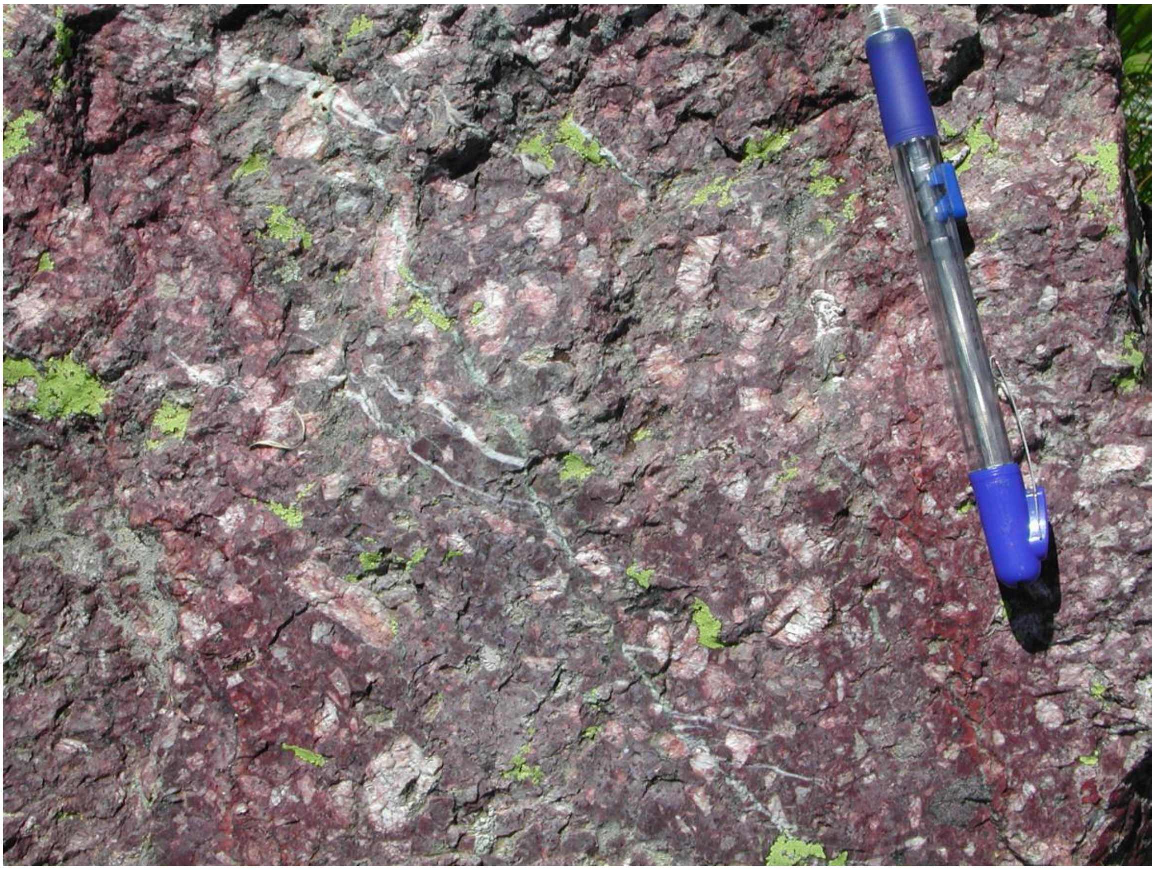


Fig. 5

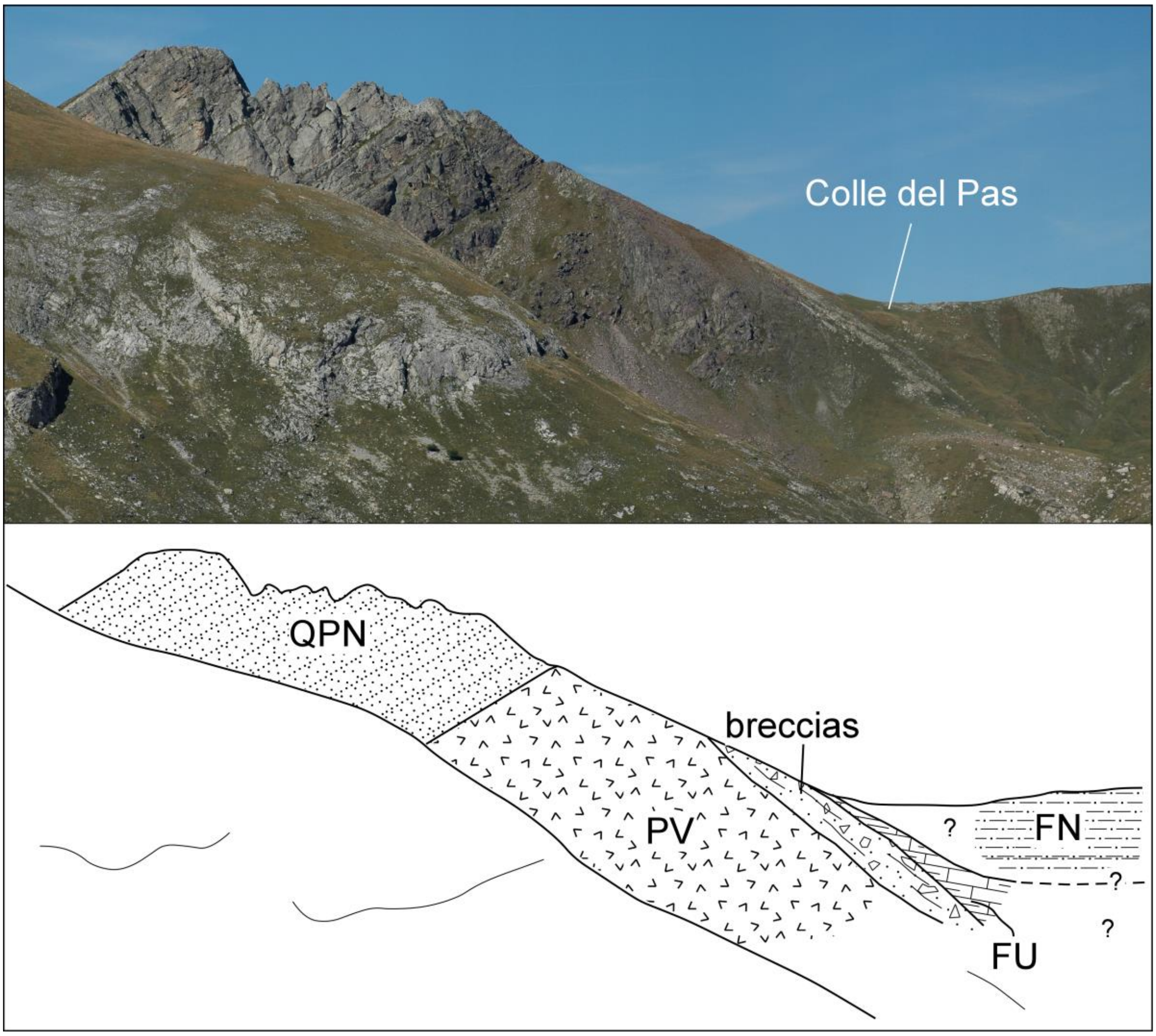


Fig. 6

Fig. 7

Fig. 8

Fig. 9

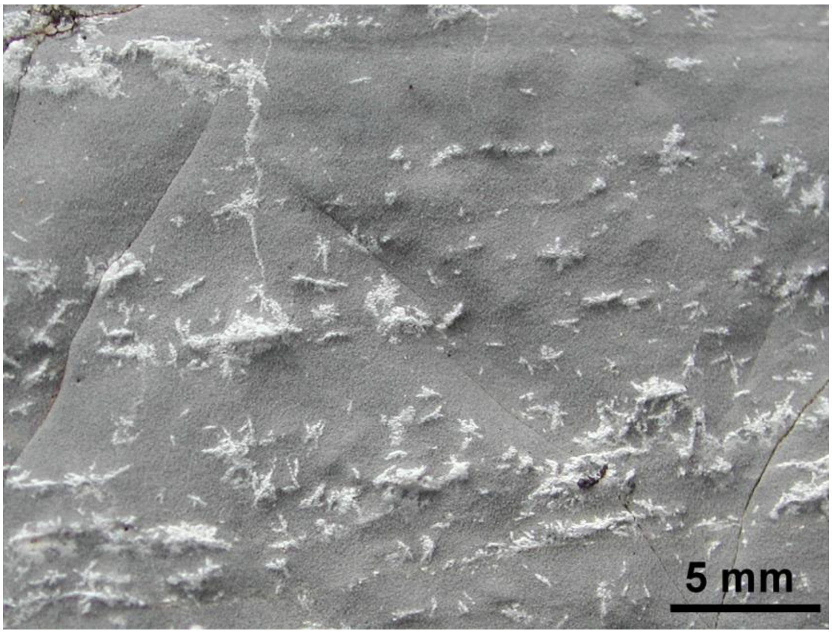


Fig. 10

Fig. 11

Fig. 12